MGB1000
Micro Gas Blender
OPERATING MANUAL

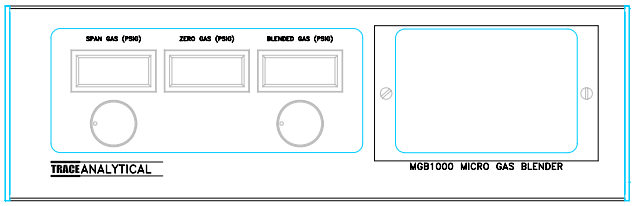

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TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

Declaration of Conformity

Manufacturer's Name:	**AMETEK (ISO 9001:2000 Registered)**
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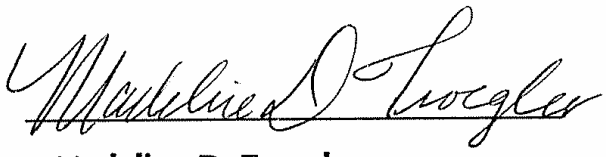
Declare under our sole responsibility that the product:

Product Name:	**Microgas Blender**
Model Number(s)	**MGB1000**

Conforms to the following standards:

LV Directive 73/23/EEC:

IEC 61010-1	*2nd Edition*	*Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1.*



Madeline D. Troegler
Quality Assurance Manager
Newark, Delaware
June 9, 2006

INTRODUCTION

The Trace Analytical manual gas blender MGB1000 generates volumetric gas blends using calibrated flow restricting orifices. Two gas streams may be blended to any predetermined mixing ratio. The MGB1000 is a 100% type 316L stainless steel gas blender, without potentially contaminating polymeric seals in any gas flow paths. The blender's efficient operating principle can produce single step dilutions of 25,000:1 while consuming less than 1.2 liters/min. total of input gases. The inherent low gas consumption and high dilution ratios obtainable with the MGB1000 can economically extend the use of common "ppm" level calibration standards to the "sub-ppb" range.

1.1 MGB1000 SPECIFICATIONS

Gas Inputs:	N_2 standard; He, H_2, O_2, Air, Argon Optional
Gas Connection Fittings:	1/16" VICI Chromatographic Fittings (1/4" VCR Male Optional)
Input Pressures (standard):	20-120 PSIG (1.4-14 Kg/cm^2), Other Ranges Optional
Output Pressure (standard):	0.5-3.0 PSIG (0.04-0.2 Kg/cm^2) Other Ranges Optional
Output Flow (standard):	40 ml/min; Flows to 1500 ml/min optional
Power Input:	115 or 230Vac $\pm$10%, 50/60 Hz, 60 W
Dimensions & Weight:	16.75" W x 5.25" H x 16.25” Deep, 10 lb.
Mounting:	Bench (Standard), 19" Rack Mount Optional
Environment:	Indoor Use Ambient Temp: 5 – 40°C IEC Installation (Overvoltage) Category: II IEC Pollution Degree 2 Max. Altitude: 2000 meters Relative Humidity: 0% to 80%, non-condensing
Construction:	100% Type 316 Stainless Steel Tubing Type 316 Stainless Steel Pressure Transducers

Stability:	Restrictors: ± 2% of reading / year Transducers: ± 0.1 psi / year
Repeatability:	Restrictors: ± 1% of reading Transducers: ± 0.05 psi

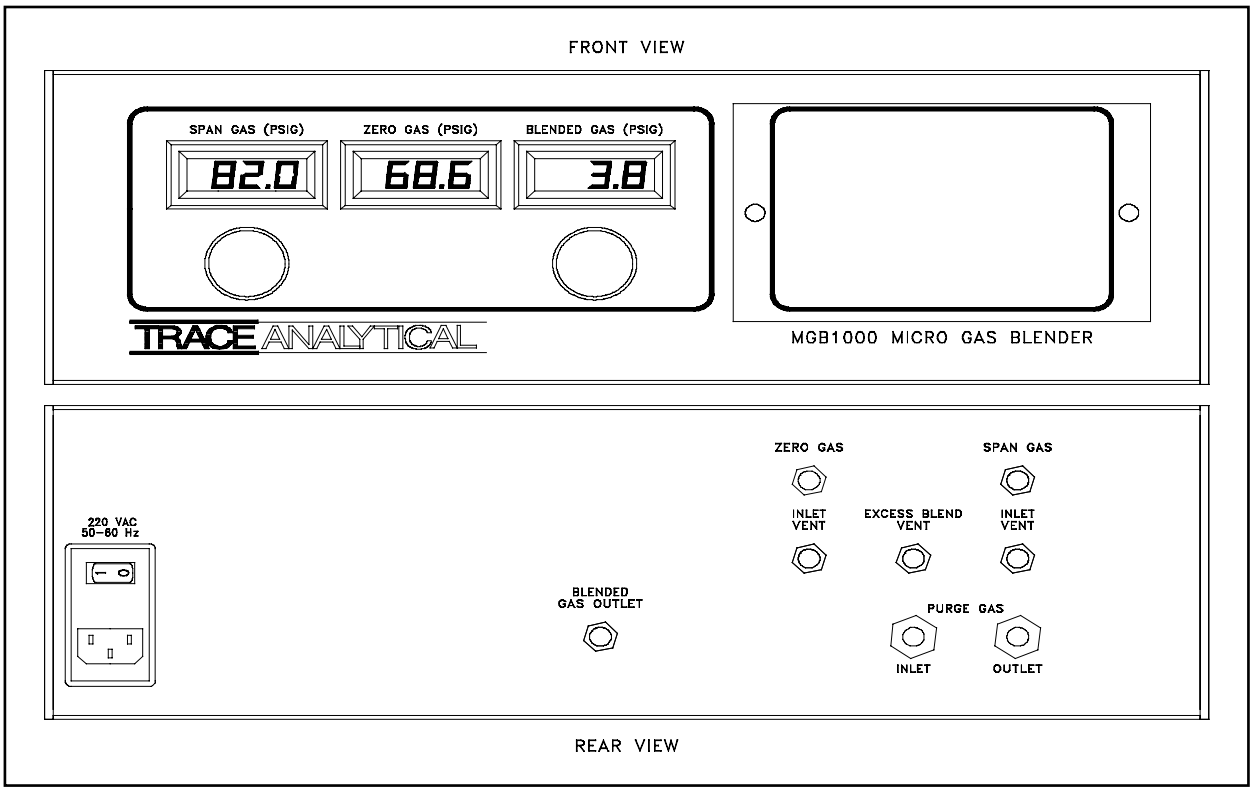
2 GENERAL INSTALLATION CONSIDERATIONS:

WARNING! ALL GAS FITTINGS IN THE MGB1000 CONTAIN 2 MICRON PARTICLE SCREENS. REMOVAL OF INTERNAL GAS CONNECTIONS COULD DESTROY THE GAS FLOW PATH INTEGRITY. CONSULT FACTORY PRIOR TO ANY SERVICING.

WARNING! WHEN BLENDING EXPLOSIVE GASES SUCH AS H_2, O_2, ETC. A PURGE FLOW OF 200 ml/min WITH NON-COMBUSTIBLE GAS IS RECOMMENDED.

1. Thoroughly purge all gas lines before connection to the MGB1000 to avoid loading the internal filters with foreign debris.
2. For optimum performance, plumb all gas lines with the smallest possible internal diameter tubing.
3. Maintain the minimum sample exit flow rates shown below, or as required by manufacturer's specifications.

Tubing Internal Diameter	Minimum N_2 Flow to Prevent Atmospheric Back Diffusion (ml/min)
0.01"	1.67
0.02"	6.67
0.03"	15
0.063"	65
0.085"	120
0.150"	375



3 PRINCIPLE OF OPERATION

The MGB1000 blender utilizes an ultra-high purity, non-contaminating, bakeable plumbing system to perform volumetric mixing of two gas streams. The plumbing schematic for a typical calibration gas dilution is shown in Figure 1 with all type 316 stainless steel tubing highlighted in bold lines. Note that the tubing entering and exiting the mixing volume is type 316 stainless steel and contaminating components (regulators, transducers) are located in downstream side branches. Adequate side branch "vent" flow is maintained at all times to sweep contaminants away from the mixing volume. All gases entering and exiting the MGB1000 are filtered for particulates larger than 2 .

In Figure 1, it can be seen that SPAN GAS enters the rear bulkhead and passes through a flow limiting restrictor R_S. This restrictor serves to limit the maximum SPAN gas consumption to ca. 75 ml/min under all circumstances. Gas flow is split at T1 to feed the mixing volume via restrictor R_C, with the balance of the flow passing through the pressure transducer and regulator BPR1 before exiting via the SPAN GAS VENT. ZERO GAS entering the MGB1000 is immediately split at T4 feeding the mixing volume via restrictor R_Z and the pressure transducer and flow limiter restrictor R_V before exiting through the ZERO GAS VENT bulkhead.

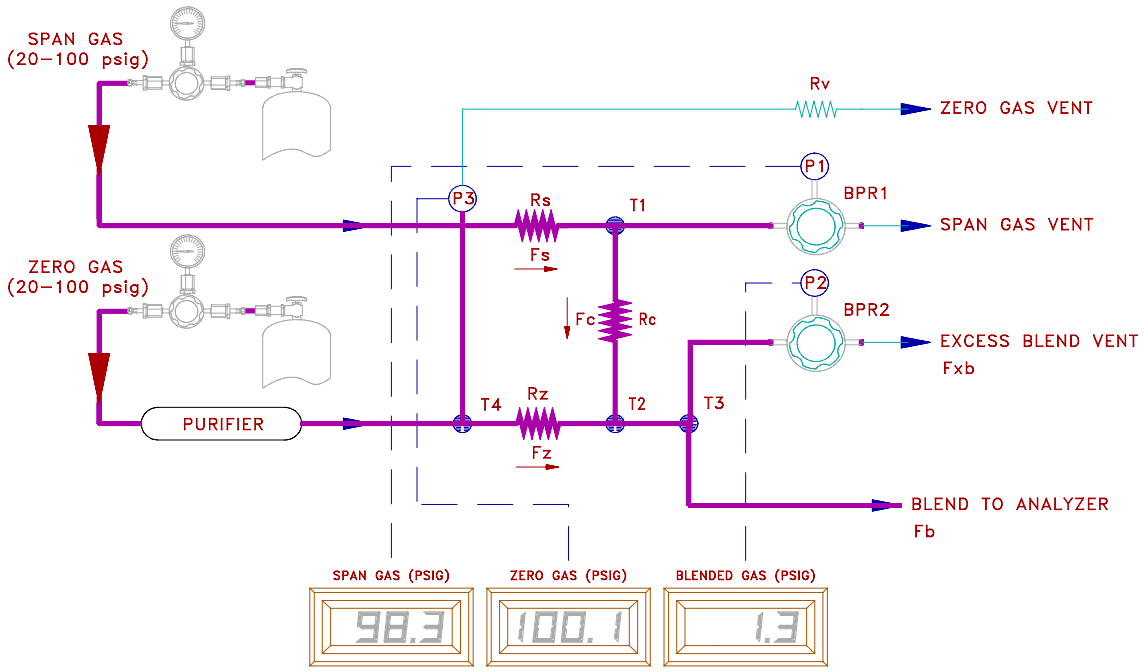


Figure 1 Plumbing Schematic for the MGB1000.

The mixing ratio is regulated by the relative ratio of flows through R_Z and R_C. As seen in Figure 2, flow through a restrictor is direct function of pressure applied. Therefore, the mixing ratio can be controlled with simple pressure regulator adjustments.

All gas pressures in the MGB1000 are displayed on the front panel via LCD's. Standard gauge units are PSIG.

The side branched regulator arrangements in the MGB1000 allows gas pressure to be controlled directly from the front panel while maintaining gas integrity. The standard MGB1000 plumbing arrangement as illustrated in Figure 1 utilizes this plumbing method for the SPAN and BLENDED gas pressure control. Typically, the ZERO gas pressure is controlled by a customer supplied external UHP regulator located upstream of a purifier to maintain the highest absolute ZERO gas purity. The use of an external ZERO regulator also minimizes the "vent" loss of costly purified diluent.

For situations where purified ZERO gas is readily available, an optional internal side branched ZERO gas pressure regulator with front panel control is available, please consult AMETEK for details.

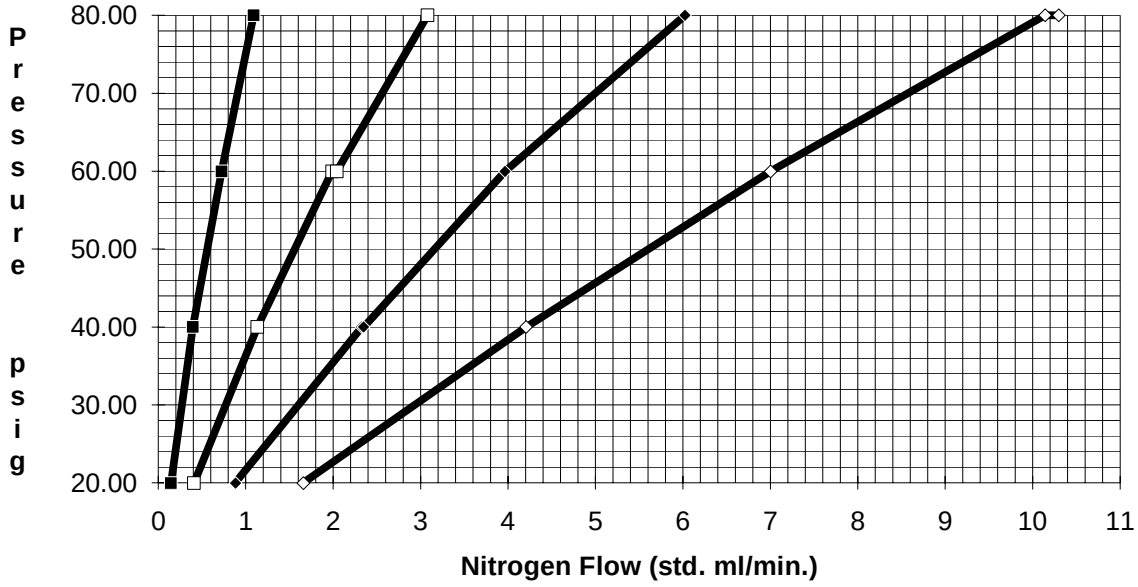


Figure 2 Flow Response of Several Restrictors to Applied Pressure.

3.1 BLEND RATIO DETERMINATION AND CONTROL

In Figure 1, SPAN and ZERO gas flows F_C and F_Z mix in the tubular volume between T2 and T3. The exact mixing ratio is determined by the relative volumetric flow in the mixing chamber. Blend ratio and final concentration of the blended gas is governed by the equation of mass balance:

$$[Final] = ((F_c) \bullet [Span] + (F_z) \bullet [Zero]) / ((F_b) + (F_{xb})) \quad \text{Eq. 1}$$

where: [ ] = concentration of any species in each gas stream
F_c = flow through span gas restrictor
F_z = flow through zero gas restrictor
F_b = flow exiting through the BLENDED GAS OUTLET
F_{xb} = flow exiting through the EXCESS BLEND VENT

If the ZERO gas stream is adequately purified, the concentration of contaminants in that stream is negligible, $(F_z \bullet [Zero]) = 0$, and Equation 1 becomes:

$$[Final] = [Span] \bullet (F_c) / ((F_b) + (F_{xb})) \qquad \text{Eq. 2}$$

Further examination of Figure 1 and application of conservation of mass flow reveals that:

$$((F_b) + (F_{xb})) = ((F_c) + (F_z)) \qquad \text{Eq. 3}$$

Substituting Equation 3 into Equation 2 yields:

$$[Final] = [Span] \bullet (F_c) / ((F_c) + (F_z)) \qquad \text{Eq. 4}$$

The restrictor calibration curves for the MGB1000 can be used to predict output blend ratio as a function of span gas and zero gas pressure and restrictor choice. Tabulated results for the MGB1000 are included in Appendix A to the manual, a typical portion is reproduced in Table 1. Columns 1 and 2 in Table 1 refer to the front panel LCD values for the respective gas stream pressures. The values listed in columns 3, 4, and 5 are for the calculated quantity $(F_c)/((F_c) + (F_z))$ in Equation 4 for each restrictor.

Zero Pressure (psig)	Span Pressure (psig)	Calculated Blend Ratio		
		Blue Restrictor	Red Restrictor	Green Restrictor
30.0	**20.0**	0.00064	0.00213	0.03517
	40.0	0.00163	0.00586	0.08301
	60.0	0.00293	0.01113	0.13699
	80.0	0.00486	0.01704	0.19157
	100.0	0.00690	0.02498	0.24121
60.0	**20.0**	0.00028	0.00093	0.01567
	40.0	0.00071	0.00257	0.03803
	60.0	0.00128	0.00489	0.06483
	80.0	0.00213	0.00752	0.09378
	100.0	0.00303	0.01107	0.12191
90.0	**20.0**	0.00018	0.00061	0.01025
	40.0	0.00046	0.00167	0.02508
	60.0	0.00083	0.00319	0.04316
	80.0	0.00139	0.00490	0.06309
	100.0	0.00197	0.00723	0.08285

Table 1 Output Blend Ratio versus Pressures and Restrictor Choice.

For the simple case of SPAN gas dilution with a pure ZERO gas, Equation 4 becomes:

$$[Final] = [Span] \bullet \text{Chart Value} \qquad \text{Eq. 5}$$

and the blended concentration of any species equals the appropriate column 3, 4, or 5 value multiplied by the span gas concentration.

As an illustration, assume a N_2 span gas dilution with pure (zero) N_2 under the following conditions:

ZERO GAS PRESSURE *60.0 psig*
SPAN GAS PRESSURE *80.0 psig*
RESTRICTOR CHOICE *RED*
SPAN GAS CONCENTRATIONS
H_2 = 665 ppb, CO = 1407 ppb, CH_4 = 1082 ppb, CO_2 = 968 ppb, Balance N_2
ZERO GAS CONCENTRATIONS
less than 100 ppt of any contaminant in N_2

Reading values from Table 1, the output blend ratio will be 0.00752. Substituting this value in Equation 5, the outlet blended gas concentration is calculated to be:

H_2 = 5.0 ppb, CO = 10.6 ppb, CH_4 = 8.1 ppb, CO_2 = 7.3 ppb, Balance N_2

The blend ratio chart can also be used for the more generalized case in which the span gas and zero gas contain measurable quantities of contaminants. Rearranging Equation 3 yields:

$$(F_z) / ((F_b) + (F_{xb})) = 1 - [(F_c) / ((F_b) + (F_{xb}))] \qquad \text{Eq. 6}$$

therefore:

$$(F_z) / ((F_b) + (F_{xb})) = 1 - \text{Chart Value} \qquad \text{Eq. 7}$$

Combining Equation 7 with Equation 1 yields the generalized blend ratio calculation:

$$[Final] = (\text{Chart Value} \bullet [Span] + (1 - \text{Chart Value}) \bullet [Zero]) \qquad \text{Eq. 8}$$

where: [ ] = concentration of any species in each stream

For comparison to the first example, assume a N_2 span gas dilution with impure N_2 under the following conditions:

ZERO GAS PRESSURE *60.0 psig*
SPAN GAS PRESSURE *80.0 psig*
RESTRICTOR CHOICE *RED*
SPAN GAS CONCENTRATIONS
H_2 = 665 ppb, CO = 1407 ppb, CH_4 = 1082 ppb, CO_2 = 968 ppb, Balance N_2
ZERO GAS CONCENTRATIONS
H_2 = 5 ppb, CO = 60 ppb, CH_4 = 4 ppb, CO_2 = 20 ppb, Balance N_2

As before, the output blend ratio will be 0.00752. Substituting this value into Equation 8, the contributions to the outlet blended gas concentration are calculated to be:

H_2 = 5.0 ppb, CO = 10.6 ppb, CH_4 = 8.1 ppb, CO_2 = 7.3 ppb from SPAN GAS
H_2 = 4.97 ppb, CO = 59.55 ppb, CH_4 = 3.96 ppb, CO_2 = 19.85 ppb from ZERO GAS

giving a total contaminant concentration of:

H_2 = 9.97 ppb, CO = 70.16 ppb, CH_4 = 12.06 ppb, CO_2 = 27.15 ppb, Balance N_2

By comparing these results to the first example, the importance of extremely pure diluent for the ZERO gas stream is clear: relatively minor concentrations of ZERO gas contaminants can quickly overwhelm the SPAN gas additions.

3.2 CALIBRATION AND BLEND ACCURACY

Flow restrictors have been found to be very stable and reproducible over extended periods of time, reducing the need for frequent calibration. Figure 3 shows the stability and reproducibility of a standard orifice restrictor over approximately 2 years of use. In this example, when measured with a bubble flow meter, the nominal flow at any applied pressure varied less than 2.0%, nearly the limit of accuracy of bubble flow meter methods.

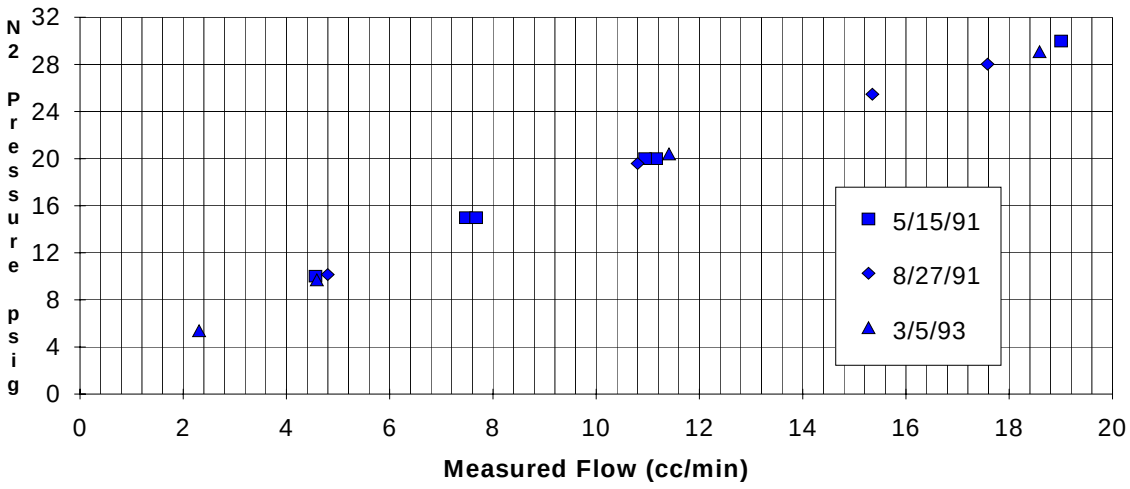


Figure 3 The flow characteristics of an orifice restrictor over extended time.

All restrictors in the MGB1000 are factory calibrated with N_2 gas using bubble flow meters and standard gauges at the prevailing room temperature and atmospheric pressure. The calibration results are presented in Appendix A in tabular and graph formats. Calibrations with gases other than N_2 are available, please consult the factory for details.

By using the tabulated values as a rough guideline and making a few simple flow measurements, the MGB1000 can easily be adjusted to provide any specific blend ratio. The standard recommended arrangement of ta3000/ta5000 and MGB1000 for span gas dilution is shown in Figure 4. In this configuration, the blended gas outlet flow F_b (after passing through the analyzer) and the excess blend vent flow F_{xb} are recombined to provide a single measurement point for the total blend gas flow . The quantity $((Fb) + (Fxb))$ can be measured directly with a bubble flow meter or mass flow meter. Actual blend ratio is then calculated manually using the tabulated values of SPAN gas flow versus SPAN gas pressure in Appendix A.

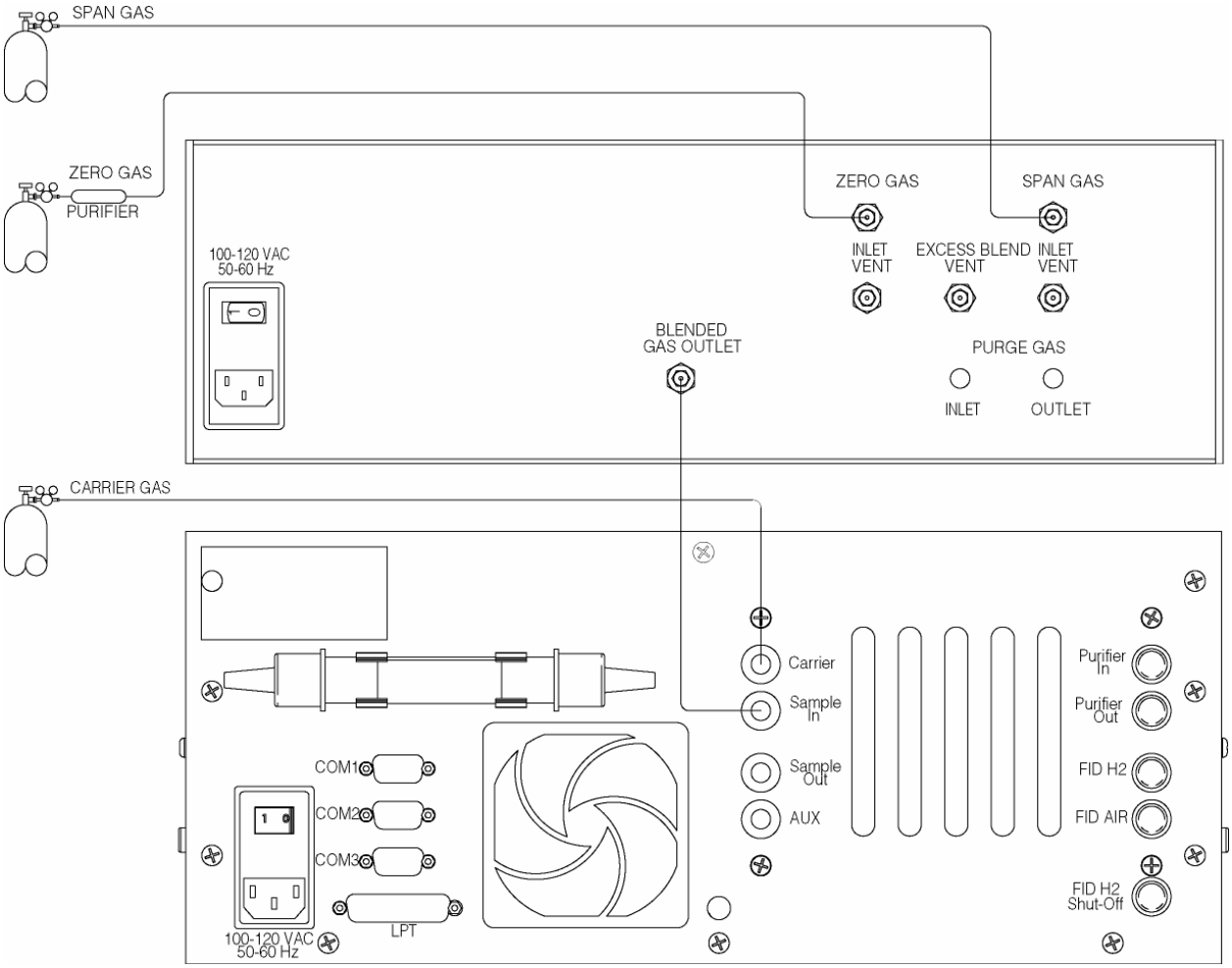


Figure 4 Typical plumbing arrangement of the ta3000 and MGB1000

As an illustration of the manual adjustment method for the MGB1000, return to the first example of N_2 span gas dilution with pure (zero) N_2 under the following conditions:

ZERO GAS PRESSURE	*60.0 psig*
SPAN GAS PRESSURE	*80.0 psig*
RESTRICTOR CHOICE	*RED*

SPAN GAS CONCENTRATIONS

H_2 = 665 ppb, CO = 1407 ppb, CH_4 = 1082 ppb, CO_2 = 968 ppb, Balance N_2

ZERO GAS CONCENTRATIONS

less than 100 ppt of any contaminant in N_2

The resultant gas blend was:

H_2 = 5.0 ppb, CO = 10.6 ppb, CH_4 = 8.1 ppb, CO_2 = 7.3 ppb, Balance N_2

For the current example, assume a 10.0 ppb CO concentration is desired for calibration purposes. In this case, the user could decrease SPAN gas flow or increase ZERO gas

flow to achieve the desired blend. The following sequence of adjustments illustrate SPAN gas flow adjustment:

Step 1. Determine the appropriate blend ratio. It is calculated by:
Blend Ratio = [Desired] / [Span] = 10.0 / 1407.0 = 0.00711

Step 2. Determine the approximate pressure and correct restrictor choices from the tabulated blend ratios.

Step 3. Measure the total blended gas flow $((F_b) + (F_{xb}))$.

Step 4. Obtain the restrictor flow for the SPAN pressure from Step 2.

Step 5. Calculate the required SPAN gas flow $(F_c) = \text{Blend Ratio} \bullet ((F_b) + (F_{xb}))$

Step 6. Calculate the adjusted SPAN pressure by:
Desired Pressure = (New SPAN flow)•((Initial SPAN pressure)/(Initial SPAN flow))
= (0.00711 / 0.00752)•80.0 psig = 75.6 psig

Step 7. Adjust SPAN pressure to calculated value from step 6.

Step 8. Measure the new total blended gas flow $((F_b) + (F_{xb}))$.

Step 9. Calculate the new blend ratio by $(F_c)/((F_b) + (F_{xb}))$.

Step 10. Calculate the blended gas concentration.

It may be necessary to reiterate steps 1 through 10 to obtain the blend concentration within your desired measurement error.

3.3 SOURCES OF ERROR AND CORRECTIONS

Since the flow of gas through fixed restrictors is a function of net pressure across each restrictor, the blend ratio calculation can become inaccurate when the blended gas pressure becomes a significant percentage of the SPAN or ZERO gas pressure. This effect can be calculated from gas dynamics as follows:

$$q_s / q_s' = ((P_{in} - P_b) / P_{in}) \bullet ((P_{in} + P_s + P_b) / (P_{in} + P_s)) \quad \text{Eq. 9}$$

where:
q_S = volumetric flow at STP (0°C, 1 atm)
q_S' = volumetric flow at actual temperature and pressure
P_{in} = Restrictor Inlet pressure (SPAN or ZERO LCD gauge)
P_S = STP pressure (1 atm = 14.7 psia)
P_b = Blended Gas Pressure (BLENDED GAS LCD gauge)

Examination of Table 2 shows good correlation between theory and experimental data as the BLENDED gas pressure was varied from 0 psig up to 10 psig.

SPAN GAS pressure ($=P_{in}$) (psig)	Theory **q_S/q_S'**	**Restrictor #1 qs/qs'** q_S @ 0 psig, q_S' @ 10 psig BLENDED GAS pressure	**Restrictor #2 qs/qs'** q_S @ 0 psig, q_S' @ 10 psig BLENDED GAS pressure
100	**0.979**	**1.008**	**0.960**
80	**0.967**	**0.980**	**0.960**
60	**0.945**	**0.959**	**0.924**
40	**0.887**	**0.919**	**0.847**
20	**0.644**	**0.665**	**0.350**
Linear regression analysis of experimental data to theory			
	R^2	0.9962	0.9931
	Error	0.00989	0.02496

Table 2 Comparison of Measured vs. Theoretical qs/qs'

Table 2 data also shows that no appreciable effect from changes in BLENDED gas pressure occurs until P_{in} is approximately 40 psig (=25% of SPAN pressure). Also note that at 60 psig SPAN gas pressure, BLENDED gas pressure changes representing up to 16% of the applied SPAN pressure affect the measured flow only 3.5%.

Additionally, measurements of changes in detected blend concentrations as BLENDED gas pressure is varied from 0 psig to 10 psig supports the theory. Table 3 shows the effect of increasing BLENDED gas pressure on measured blend ratio.

Span Gas Pressure	**Zero Gas Pressure**	**Blended Gas Pressure**	**Blend Pressure (% of Span)**	**Measured Blend Ratio Change**
20	20	0.5	2.5%	
20	20	2.0	10%	-0.68%
20	20	0.5	2.5%	
20	20	5.0	25%	-1.43%
20	20	10.0	50%	-6.88%
20	60	0.5	2.5%	
20	60	5.0	25%	-10.02%
20	60	10.0	50%	-35.19%
20	60	0.8	3.9%	
20	60	10.0	49%	-36.51%
30	30	0.5	1.7%	
30	30	5.0	16.7%	-1.89%
30	30	10.0	33.3%	-3.13%
30	60	0.5	2.3%	
30	60	5.0	16.7%	-12.23%

Table 3 continued

Span Gas Pressure	Zero Gas Pressure	Blended Gas Pressure	Blend Pressure (% of Span)	Blend Ratio Change
30	100	1.3	4.4%	
30	100	5.0	16.8%	-8.04%
30	100	10.0	33.3%	-16.85%
60	60	0.6	1.0%	
60	60	5.0	8.3%	-1.97%
60	60	10.0	16.6%	-5.45%

Table 3 Variability of Blend Ratio with Increasing Blend Pressure

Based upon these results, a general guideline for SPAN, ZERO, and BLENDED gas pressure ratios can be established where the effect of change in BLENDED gas pressure on MGB1000 output blend concentration is negligible.

FOR GENERAL OPERATION, TRACE ANALYTICAL RECOMMENDS THAT THE BLENDED GAS PRESSURE NOT EXCEED 10% OF THE SPAN OR ZERO GAS PRESSURE SETTING.

For those special circumstances where higher than normal BLENDED gas pressures are required, specially calibrated restrictors are available. Please consult AMETEKfor details.

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